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FORM PTO-1390 (REV. 5-93) U S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE	ATTORNEY'S DOCKET NUMBER 10191/1517
TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371	U.S. APPLICATION NO. (If known, see 37 CFR 1.5) 09/622802

INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED
PCT/DE99/00433	(16.02.99) 16 February 1999	(27 02.98) 27 February 1998

TITLE OF INVENTION
INTERFEROMETRIC MEASURING DEVICE FOR DETECTING THE SHAPE OR DISTANCE IN PARTICULAR OF ROUGH SURFACES

APPLICANT(S) FOR DO/EO/US
DRABAREK, Pawel.

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This is an express request to begin national examination procedures (35 U.S.C. 371(f)) immediately rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1).
4. ☒ A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
5. ☒ A copy of the International Application as filed (35 U.S.C. 371(c)(2))
   a. ☐ is transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☒ has been transmitted by the International Bureau.
   c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US)
6. ☒ A translation of the International Application into English (35 U.S.C. 371(c)(2))
7. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))
   a. ☐ are transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☐ have been transmitted by the International Bureau.
   c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   d. ☒ have not been made and will not be made.
8. ☐ A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ☒ An oath or declaration of the inventor(s) (35 U S.C. 371(c)(4)). (unsigned)
10. ☒ A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C 371(c)(5)).

Items 11. to 16. below concern other document(s) or information included:

11. ☒ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
12. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. ☒ A **FIRST** preliminary amendment.
    ☐ A **SECOND** or **SUBSEQUENT** preliminary amendment.
14. ☐ A substitute specification.
15. ☐ A change of power of attorney and/or address letter.
16. ☒ Other items or information: Copies of International Search Report, Preliminary Examination Report and Form PCT/RO/101.

EXPRESS NO.: EL302700255US

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U.S. APPLICATION NO. if known, see 37 C.F.R. 1.5 09/622802	INTERNATIONAL APPLICATION NO PCT/DE99/00433	ATTORNEY'S DOCKET NUMBER 10191/1517

17. ☒ The following fees are submitted

	CALCULATIONS	PTO USE ONLY
Basic National Fee (37 CFR 1.492(a)(1)-(5)): Search Report has been prepared by the EPO or JPO .... $840.00 International preliminary examination fee paid to USPTO (37 CFR 1.482) ... $670.00 No international preliminary examination fee paid to USPTO (37 CFR 1.482) but international search fee paid to USPTO (37 CFR 1.445(a)(2)) .... $750.00 Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO .... $970 00 International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(2)-(4) $96.00		
ENTER APPROPRIATE BASIC FEE AMOUNT =	$840	
Surcharge of $130.00 for furnishing the oath or declaration later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1 492(e)).	$	

Claims	Number Filed	Number Extra	Rate		
Total Claims	11 - 20 =	0	X $18.00	$ 0	
Independent Claims	1 - 3 =	0	X $78.00	$ 0	
Multiple dependent claim(s) (if applicable)			+ $260.00	$	
TOTAL OF ABOVE CALCULATIONS =				$ 840	
Reduction by ½ for filing by small entity, if applicable. Verified Small Entity statement must also be filed. (Note 37 CFR 1.9, 1.27, 1.28).				$	
SUBTOTAL =				$ 840	
Processing fee of $130.00 for furnishing the English translation later the ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492(f)). +				$	
TOTAL NATIONAL FEE =				$ 840	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). $40.00 per property +				$	
TOTAL FEES ENCLOSED =				$ 840	
				Amount to be: refunded	$
				charged	$

a. ☐ A check in the amount of $__________ to cover the above fees is enclosed.

b. ☒ Please charge my Deposit Account No. 11-0600 in the amount of **$840.00** to cover the above fees. A duplicate copy of this sheet is enclosed

c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 11-0600. A duplicate copy of this sheet is enclosed.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:

Kenyon & Kenyon
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New York, New York 10004

By: [signature] 40352

[signature]
SIGNATURE

Richard L. Mayer, Reg. No. 22,490
NAME

8/22/00
DATE

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EXPRESS MAIL CERTIFICATE

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DATE OF DEPOSIT 8/22/00

TYPE OF DOCUMENT National Phase Application: Pawel DRABAREK

SERIAL NO. To be assigned FILING DATE Herewith

I HEREBY CERTIFY THAT THIS PAPER OR FEE IS BEING DEPOSITED WITH THE UNITED STATES POSTAL SERVICE "EXPRESS MAIL POST OFFICE TO ADDRESSEE" SERVICE UNDER 37 CFR 1.10 ON THE DATE INDICATED ABOVE, BY BEING HANDED TO A POSTAL CLERK OR BY BEING PLACED IN THE EXPRESS MAIL BOX BEFORE THE POSTED DATE OF THE LAST PICK UP, AND IS ADDRESSED TO THE ASSISTANT COMMISSIONER FOR PATENTS, WASHINGTON, D.C. 20231.

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(TYPED OR PRINTED NAME OF PERSON MAILING PAPER OR FEE)

(SIGNATURE OF PERSON MAILING PAPER OR FEE)

Interferometric Measuring Device For Detecting The Shape or Distance in Particular of Rough Surfaces

09/622802
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[10191/1517]

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Inventor(s)	:	Pawel DRABAREK
Serial No.	:	To Be Assigned
Filed	:	Herewith
For	:	INTERFEROMETRIC MEASURING DEVICE FOR DETECTING THE SHAPE OR DISTANCE IN PARTICULAR OF ROUGH SURFACES
Examiner	:	To Be Assigned
Art Unit	:	To Be Assigned

Assistant Commissioner for Patents
Washington, D.C. 20231

PRELIMINARY AMENDMENT

SIR:

Kindly amend the above-identified application before examination, as set forth below.

IN THE SPECIFICATION:

Please amend the specification as follows.

On page 1, before line 1, insert:
--FIELD OF THE INVENTION--.

On page 1, line 2, change "distance in particular" to --distance, in particular,--.

On page 1, line 3, change "surfaces, having" to --surfaces. The interferometric measuring device has--.

On page 1, line 7, change "surface, also having" to --surface;--.

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On page 1, line 13, change “beam, also having” to --beam;--.

On page 1, line 16, change “signals, and also having” to --signals; and--.

On page 1, before line 21, insert:
--BACKGROUND INFORMATION--.

On page 1, line 21, change “known from” to --described in--.

On page 1, line 22, change “126 475 B1. In this known” to --No. 0 126 475. In this conventional--.

On page 1, line 24, change “interferometrically, a beam gun unit having” to --interferometrically. A beam gun unit that has--.

On page 1, line 25, change “sources” to --sources,--, and change “wavelengths being” to --wavelengths, is--.

On page 2, line 6, change “used, the” to --used. The--, and change “being” to --is--.

On page 2, line 11, change “having” to --that has--.

On page 2, line 36, change “39 06 118 A1" to --No. 39 06 118--.

On page 3, line 2, change “known” to --conventional measuring device--.

On page 3, line 3, delete “design”.

On page 3, before line 6, insert:

--<u>SUMMARY</u>--.

On page 3, line 6, change “The” to --An--.

On page 3, line 7, delete “of the type”.

On page 3, line 8, delete “mentioned in the preamble,”.

On page 3, line 14, change “This” to --The--, and change “features of Claim 1" to --the present invention--.

On page 3, line 18, delete “it has been found that”.

On page 3, line 19, change “having at the same time” to --that have--.

On page 4, line 4, change “multiplex” to --multiplexing--.

On page 4, delete lines 9-12, and insert: --fibers, for example.

The present invention also has an embodiment that is advantageous for--.

On page 4, line 13, change “design” to --embodiment--.

On page 5, line 1, change “having” to --that has--.

On page 5, line 3, delete “is”.

On page 5, line 4, change “arrangement is favorable for the” to --arrangement, is favorable for--.

On page 5, line 5, delete “the”.

On page 5, line 16, change “having” to --that has--.

On page 5, line 17, change “arm, an” to --arm. An--.

On page 5, delete lines 27-32, and insert:

--BRIEF DESCRIPTION OF THE DRAWING

The Figure schematically shows an arrangement of components of an interferometric measuring unit for detecting the shape of rough surfaces.

DETAILED DESCRIPTION--.

On page 5, line 36, after “4" insert: --that has a rough surface to be measured is--.

On page 5, delete line 37, and insert: --rotating table 15 and is--.

On page 6, line 7, change “8 and” to --8,--.

On page 6, line 10, change “as well as” to --and--.

On page 6, line 14, change “conceivable” to --possible--.

On page 6, line 19, change “having” to --that have---.

On page 6, line 31, change “designed” to --designed, for example--.

On page 6, line 37, change “which” to --that--.

On page 7, line 3, change “having” to --that has--.

On page 7, line 13, change “in the form of” to --as--.

On page 7, line 16, change “3 and of” to --3, and--.

On page 8, line 2, change “difference” to --difference,--.

On page 8, line 4, change “modulators” to --modulators,--.

On page 8, line 15, change “having” to --that has--.

On page 8, line 35, delete “above-described design of”.

On page 8, line 36, after “1" insert --according to the present invention--, and change “having” to --that has--.

On page 9, line 2, change “having” to --that has--.

On page 9, line 3, change “analyzer” to --analyzer,--.

On page 9, line 6, change “deviations” to --deviations,--.

<u>IN THE ABSTRACT</u>:

Delete line 1, and insert:

-- <u>ABSTRACT</u>--.

Line 3, delete “(1)”.

Line 4, change “described, a” to --described. A--.

Line 5, change “being provided, which” to --is provided that--.

Line 6, change "beam, the device being" to --beam. The device is--.

Line 8, delete "(2)".

Line 9, change "(3), and the" to --The--, and change "(3) being" to --is--.

Line 10, delete "(2)".

Line 11, change "(6), being" to --and--, and change "interferometer" to --interferometer.--.

Delete line 12.

<u>IN THE CLAIMS</u>:

On page 10, delete line 1, and insert:

--<u>What Is Claimed Is</u>:--.

Please cancel, without prejudice, claims 1-11 of the underlying PCT application, and claims 1-10 of the revised pages of the annex to the Preliminary Examination Report.

Please add the following new claims:

11. (New) An interferometric measuring device for detecting one of a shape and a distance of a rough surface, the measuring device comprising:

a measuring probe having a reference arm and a measuring arm;

at least one spatially coherent beam gun unit, a beam emitted by the at least one spatially coherent beam gun unit being broad-band and having a short time coherence, the beam emitted by the at least one spatially coherent beam gun unit being divided into a reference beam and a measuring beam, the reference beam being guided through and reflected in the reference arm,

the measuring beam being guided through the measuring arm and reflected on the rough surface;

a first beam splitter for forming a first partial beam and a second partial beam;

a first device for one of modulating a light phase and shifting a light frequency corresponding to the heterodyne frequency of the first partial beam with respect to one of a light phase and a light frequency of the second partial beam;

a superimposing unit for superimposing the reflected measuring beam on the reflected reference beam;

a beam splitting and receiving unit for splitting the superimposed beam into at least two beams and converting the at least two beams into electrical signals, the at least two beams having different wavelengths; and

an analyzer for determining the one of the shape and the distance of the rough surface as a function of a phase difference of the electrical signals, wherein:

the at least one spatially coherent beam gun unit, the first beam splitter, and the first device are arranged in a unit remote from the measuring probe, and

the unit includes a time delay element arranged in a beam path of one of the first partial beam and the second partial beam, the time delay element producing an optical path difference of optical wavelengths of the first partial beam and the second partial beam, the difference being greater than a coherence length of the beam emitted by the at least one spatially coherent beam gun unit.

12. (New) The measuring device according to claim 11, wherein:

the measuring probe is a modulation interferometer.

13. (New) The measuring device according to claim 11, wherein:

the at least one spatially coherent beam gun unit includes a light

source emitting a short time coherent broad-band beam.

14. (New) The measuring device according to claim 11, wherein:
the unit and the measuring probe are coupled to one another via an optical fiber arrangement.

15. (New) The measuring device according to claim 11, wherein:
the unit further includes a second beam splitter that receives the first partial beam and the second partial beam, the first partial beam and the second partial beam being superimposed on one another at the second beam splitter, the second beam splitter forwarding the superimposed beam to the measuring probe.

16. (New) The measuring device according to claim 13, wherein:
the at least one spatially coherent beam gun unit includes a second light source, the second light source having a short time coherent and being broad-band and spatially coherent, the second light source being operable one of for light amplification and as a backup light source.

17. (New) The measuring device according to claim 11, further comprising:
a second device for frequency shifting the first partial beam with respect to the second partial beam, the second device being arranged in the beam path of one of the first partial beam and the second partial beam; the first device and the second device being acoustical-optical modulators.

18. (New) The measuring device according to claim 14, wherein:
the beam splitting and receiving unit includes a spectral device and a downstream photo-detector matrix, the spectral device splitting the superimposed beam into a plurality of wavelengths, the downstream photo-detector matrix selectively receiving the plurality of wavelengths;
the beam splitting and receiving unit is mounted in the unit;

the beam splitting and receiving unit is coupled to the measuring probe via the optical fiber arrangement; and

phase differences of signals from individual detectors of the photo-detector matrix are used for determining the one of the shape and the distance of the rough surface.

19. (New) The measuring device according to claim 11, wherein:

the measuring probe has a beam splitter, the measuring probe being one of a Michelson interferometer and a Mirau interferometer; and

an optical path difference produced in the measuring arm and the reference arm compensates for the optical path difference produced by the time delay element.

20. (New) The measuring device according to claim 14, further comprising:

a second beam splitting and receiving unit arranged in the unit; and

a reference probe having a reference arm and a measuring arm, the reference probe being coupled to the unit via a second optical fiber arrangement, a second beam path being formed from the second beam splitter to the reference probe.

21. (New) The measuring device according to claim 11, wherein:

the measuring device is used for measuring an internal geometry of a borehole.

Remarks

This Preliminary Amendment cancels, without prejudice, claims 1-11 in the underlying PCT Application No. PCT/DE99/00433. This Preliminary Amendment also cancels, without prejudice, claims 1-10 of the revised pages of the Preliminary Examination Report, and adds new claims 11-21. The new claims conform the claims to U.S. Patent and Trademark Office rules and do not add new matter to the application.

The above amendments to the specification and abstract conform the specification and abstract to U.S. Patent and Trademark Office rules, and do not introduce new matter into the application.

The underlying PCT Application No. PCT/DE99/00433 includes an International Search Report, dated July 22, 1999. The Search Report includes a list of documents that were uncovered in the underlying PCT Application. A copy of the Search Report is included herewith.

The underlying PCT Application No. PCT/DE99/00433 also includes a Preliminary Examination Report, dated May 16, 2000. An English translation of the Preliminary Examination Report is submitted herewith.

It is respectfully submitted that the subject matter of the present application is new, non-obvious, and useful. Prompt consideration and allowance of the application are respectfully requested.

Respectfully submitted,

By: Reg No 33,952

Dated: 8/22/00

By:

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INTERFEROMETRIC MEASURING DEVICE FOR DETECTING THE SHAPE OR DISTANCE IN PARTICULAR OF ROUGH SURFACES

The present invention relates to an interferometric measuring device for detecting the shape or distance in particular of rough surfaces, having at least one spatially coherent beam gun unit, whose beam in a measuring probe is divided into a reference measuring beam guided through and reflected in a measuring reference arm and a measuring beam guided through a measuring arm and reflected on the rough surface, also having a device for modulating the light phase or for shifting the light frequency (heterodyne frequency) of a first partial beam with respect to the light phase or the light frequency of a second partial beam using a superposition unit for superimposing the reflected measuring beam on the reflected measuring reference beam, also having a beam splitting unit and receiving unit for splitting the superimposed beam into at least two beams having different wavelengths and converting the beams into electrical signals, and also having an analyzer, in which the shape or distance of the rough surface can be determined on the basis of a phase difference of the electrical signals.

Such an interferometric measuring device is known from European Patent 126 475 B1. In this known measuring device, rough surfaces of a measured object are measured interferometrically, a beam gun unit having laser light sources which emit light of different wavelengths being used. The laser light is divided into a reference beam of a reference beam path and a measuring beam of a measuring beam path using a beam splitter. The measuring beam path impinges on the surface to be measured, while the reference beam path is reflected on a reference surface, for example in the form of a mirror. The light reflected from the surface and the reference surface is combined in the beam splitter and

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focused, with the help of a lens, in a interferogram plane, where a speckle pattern is obtained. This speckle pattern is analyzed to determine the surface shape, a phase difference of the interferogram phases in the measuring point being determined. In order to simplify the analysis, a heterodyne process is used, the frequency of the reference beam being shifted with respect to the frequency of the measuring beam by a heterodyne frequency using a frequency shifter in the reference beam path. With this measuring device, a fine resolution of the surface shapes can be obtained. The laser light having different discrete wavelengths can be generated using individual laser light sources such as an argon laser. Such laser light sources are relatively expensive. Semiconductor lasers with a plurality of different discrete wavelengths (modes), on the other hand, are unsuitable for such interferometric measurements due to their insufficient stability and the resulting wavelength shift. As an alternative, a plurality of laser light sources such as laser diodes can be used in order to generate the different discrete wavelengths. It is technically difficult to generate the spatial coherence of the beam composed of the different wavelengths. In addition, in such laser diodes the instability of the individual discrete wavelengths is particularly unfavorable. Providing a plurality of different discrete wavelengths is therefore also costly.

In using laser light for generating the discrete wavelengths it is also difficult to accurately set the desired distance between the measuring probe and the surface (autofocus function). The design using the laser light source also makes it difficult to design the measuring part as an easy-to-handle unit which can be used, for example, instead of a mechanical probe of a measuring machine.

Another interferometric measuring device is described in German Patent Application 39 06 118 A1, in which optical fibers are provided between a plurality of laser light sources

and a measuring section. Here too, a phase difference is evaluated for determining the surface structures. This known design is also disadvantageous with regard to handling in places that are difficult to access.

The object of the present invention is to provide a heterodyne or phase interferometric measuring device of the type mentioned in the preamble, with which very accurate measurements of surface shapes and surface distances are possible under industrial conditions even on relatively difficult-to-access surfaces such as small boreholes, and which is easy to handle and has a simple design.

This object is achieved with the features of Claim 1, according to which the beam emitted by the beam gun unit is broad-band and has a short coherence time.

Surprisingly, it has been found that the broad-band, short coherence time beam gun units having at the same time a higher spatial coherence than light sources of a heterodyne interferometric measuring unit, in particular in conjunction with the measurements of rough surfaces, are not only well-suited, but also offer considerable advantages compared to laser light sources. The spatial coherence of the beam naturally results from the light source. Instabilities of the spectral beam distribution of the light source have virtually no effect on the measurements, since not only are individual fixed wavelengths always selected using the beam gun unit (e.g. grating) and the assigned beam receiving unit from the continuous spectrum in a stable manner, but, in particular, also their difference, which is important for accurate and unambiguous evaluation, is preserved in a stable manner. Changes in the intensity of the wavelengths in the case of instabilities have no effect due to the heterodyne technology, since in this case only the phases are relevant. The short time coherence beam allows an autofocus function to be implemented in a very simple manner, since the heterodyne

signal is present only for a certain distance range determined by the short coherence length between the measuring part and the surface. Furthermore the short coherence length offers the advantage that, using coherence multiplex, the entire measuring system can be divided into a modulation interferometer containing the active components and a small, sturdy, and easy-to-handle measuring part designed as a measuring probe, separated spatially therefrom by optical fibers, for example. Advantageous embodiments are given in the subclaims.

Claims 3, 4 and 5 describe a design that is advantageous for use in manufacturing. In the Mach-Zehnder design, the difference of angular dispersion is minimized due to the two acoustical-optical modulators arranged in the two partial beam paths.

If the beam gun unit has a short coherent, broad-band additional light source, which can be operated for light amplification or as a backup light source, the light intensity can be enhanced by using both light sources. As an alternative, the additional light source can be used as a backup light source in case of failure of the other light source.

The measures of an additional device for frequency shifting is arranged in the beam path of the second partial beam for frequency shifting the first partial beam with respect to the second partial beam, and the device and the additional device for frequency shifting are acoustical-optical modulators are suitable for achieving a low angular dispersion. The arrangement of modulators in the two beam paths reduces measurement errors due to temperature drifts and the related change in the refractive index of an acoustical-optical modulator, which would result in undesirable phase shifts.

Furthermore, the fact that the beam splitting and receiving

unit is a spectral device having a downstream photodetector matrix and the beam splitting and receiving unit is also mounted in the unit and is coupled to the measuring probe via the optical fiber arrangement is favorable for the design and for the evaluation.

Design and evaluation are further facilitated by the fact that the measuring probe, including the measuring arm, the measuring reference arm, and a beam splitter of the measuring probe, is designed as a Michelson or Mirau interferometer and that an optical path difference produced in the measuring arm and in the measuring reference arm compensates for the optical path difference produced by the time delay element.

An additional beam path is formed starting from the second beam splitter, leading to a reference probe having a reference probe reference arm and a reference probe measuring arm, an additional beam splitting and receiving unit is provided in the unit, and the unit is coupled to the reference probe via an additional optical fiber arrangement, so that an error of the rotating table used for moving the measuring object having the surface structure to be measured can be compensated. Furthermore the reference probe can be used for compensating a drift of the modulation interferometer provided in the unit, caused, for example, by temperature.

The present invention is elucidated below with reference to an embodiment illustrated in the drawing. The figure schematically shows an arrangement of the essential components of an interferometric measuring unit for detecting the shape of rough surfaces.

The interferometric measuring arrangement is divided into two sections, one of which is designed as unit 2 in the form of a modulation interferometer, while the other section includes a measuring probe 3 with which a measured object 4 placed on a rotating table 15 having a rough surface to be measured is

scanned, as well as a reference probe 5. Measuring probe 3 is coupled to modulation interferometer 2 via an optical fiber arrangement 6, while measuring probe 5 is connected to modulation interferometer 2 via another optical fiber arrangement 7. Modulation interferometer 2 in the form of unit 2 is designed in this example as a Mach-Zehnder interferometer and has a light source 8 and an additional light source 8', acoustical-optical modulators 9 and 9' arranged in the beam paths of a first partial beam 16 and a second partial beam 17, respectively, as well as two photodetector matrices, which are part of a beam splitting and receiving unit 13 and an additional beam splitting and receiving unit 13' as active components. A design as a Michelson interferometer is also conceivable. Modulation interferometer 2 is built into an air-conditioned, vibration-insulated housing, for example.

Light source 8 and additional light source 8', for example, superluminescent diodes, are short time coherent, broad-band light sources having a continuous spectral distribution of a plurality of different wavelengths. The light of light source 8 and the light of light source 8' are collimated and split into first partial beam 16 and second partial beam 17 by a first beam splitter 18, with light source 8 and additional light source 8' being located on different sides of beam splitter 18. Additional light source 8' can be used as a pre-adjusted backup source or for amplifying the overall light intensity. Both partial beams 16, 17 are frequency shifted with respect to one another by the two acoustical-optical modulators 9 and 9'. The frequency difference is a few kHz, for example. In one arm of modulation interferometer 2 designed as a Mach-Zehnder interferometer or a Michelson interferometer, a time delay element 10 is used, for example, in the form of a plane parallel glass plate, in the beam path downstream from acoustical-optical modulator 9' and a deflecting mirror 11'; this glass plate produces a difference of the optical path lengths of the two partial beams 16, 17 which is longer than the coherence length of light sources 8

and 8'. A deflecting mirror 11, from which the light is deflected onto a second beam splitter 12, is also arranged in the arm of modulation interferometer 2 having first partial beam 16, downstream from acoustical-optical modulator 9. The two partial beams 16, 17 are superimposed in second beam splitter 12 and injected into one or two monomode optical fiber arrangement(s). Due to the optical path difference produced by time delay element 10, the two partial beams 16, 17 do not interfere with one another. The light is guided via optical fiber arrangement 6 to measuring probe 3 and via additional optical fiber arrangement 7 to reference probe 5 and is ejected there. Measuring probe 3 and reference probe 5 are designed in the form of a Michelson or Mirau interferometer, for example, so that the optical path difference of the superimposed beams of a measuring arm 3.1 and reference arm 3.2 of measuring probe 3 and of a reference probe reference arm 5.1 and reference probe measuring arm 5.2 corresponds to the optical path difference of the two partial beams 16, 17 of modulation interferometer 2. The figure shows measuring probe 3 and reference probe 5 as a Michelson interferometer.

The measuring beam traveling through measuring arm 3.1 is focused by an optical arrangement onto the surface of measuring object 4 to be measured. The light reflected from the surface is superimposed on the reference beam returning in reference arm 3.2 to a reflecting element and injected into an optical fiber leading to beam splitting and receiving unit 13. Due to the path difference compensation, the light beams may interfere with one another. Accordingly, the light of reference probe measuring arm 5.1 is superimposed by the light of reference probe reference arm 5.2 and sent to second beam splitting and receiving unit 13' via second optical fiber arrangement 7 through an appropriate outgoing arm of second optical fiber arrangement 7.

Due to the path difference compensation in measuring probe 3

and reference probe 5, the light beams may interfere with one another. The light phase difference which is made easy to analyze using the heterodyne method in conjunction with the acoustical-optical modulators contains information about the distance of the surface to be measured of measuring object 4 and thus about its surface structure. The light returned from measuring probe 3 and reference probe 5 into modulation interferometer 2 is ejected from optical fiber arrangement 6 and additional optical fiber arrangement 7, decomposed into a plurality of colors, i.e., wavelengths with the help of a spectral element (for example, grating or prism) of beam splitting and receiving unit 13 and additional beam splitting and receiving unit 13' and focused onto the photodetector matrix. Each photodetector delivers an electrical signal having the differential frequency generated by acoustical-optical modulators 9,9' and phase φ_n, which with the surface structure and distance to the measuring object is related to the measured quantity ΔL (shape deviation, roughness) and the respective wavelength λ_n according to the equation

$$\varphi_n = \left(2\pi \lambda_n\right) \Delta \mathrm{L} \cdot 2$$

Evaluation is performed on the basis of forming the difference between the phases of the signals coming from the different photodetectors.

By measuring the phase differences of the signals from a plurality of photodetectors (multiwavelength heterodyne interferometry, see the above-mentioned document for more information) the measured quantity ΔL, which may be greater than individual light wavelengths, can be unambiguously determined in an analyzer, for example, in the form of a computer 14.

With the above-described design of interferometric measuring device 1, advantageous separation into a section having easy-

to-handle measuring probe 3 and reference probe 5 and a section having the relatively sensitive components of modulation interferometer 2 and analyzer is achieved. Short time coherent, broad-band light sources 8 and 8' allow a plurality of stable beam components of different wavelengths to be provided easily and shape deviations which may be as high as a multiple of the wavelength to be unambiguously evaluated in an improved manner.

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New Claims

1. An interferometric measuring device (1) for detecting the shape or distance in particular of rough surfaces, having at least one spatially coherent beam gun unit (8, 8'), whose beam is divided into a reference measuring beam guided through and reflected in a measuring reference arm (3.2) and a measuring beam guided through a measuring arm (3.1) and reflected on the rough surface, also having a device (9) for modulating the light phase or for shifting the light frequency corresponding to the heterodyne frequency of a first partial beam (16) with respect to the light phase or the light frequency of a second partial beam (17), also having a superimposing unit for superimposing the reflected measuring beam on the reflected measuring reference beam, also having a beam splitting and receiving unit (13) for splitting the superimposed beam into at least two beams having different wavelengths and converting the beam into electrical signals, and also having an analyzer (14), in which the shape or distance of the rough surface can be determined on the basis of a phase difference of the electrical signals,
characterized in that
the beam emitted by the beam gun unit (8,8') is broad-band and has a short time coherence;
the beam gun unit (8, 8'), a beam splitter for forming the first and second partial beams (16, 17), and the device (9) for phase modulation or frequency shift are arranged in a unit (2) remote from the measuring probe (3), designed as a modulation interferometer, and
a time delay element (10) is arranged in the unit (2) in the beam path of a partial beam, this delay element producing a difference of the optical wavelengths of the two partial beams (16, 17), which is greater than the coherence length of the beam emitted by the beam gun unit (8, 8').

2. The measuring device according to Claim 1, characterized

in that the beam gun unit (8, 8') is a light source emitting a short time coherent and broad-band beam.

3. The measuring device according to Claim 1 or 2, characterized in that the unit (2) and the measuring probe (3) are coupled to one another via an optical fiber arrangement (6).

4. The measuring device according to one of the foregoing claims, characterized in that the unit (2) has a first beam splitter (18) for forming the first and second partial beams (16, 17) and a second beam splitter which receives the first and second partial beams (16, 17) and at which the two partial beams (16, 17) are superimposed on one another and which forwards the beam sent to the measuring probe (3) (Mach-Zehnder interferometer).

5. The measuring device according to one of the foregoing claims, characterized in that the beam gun unit (8,8') has a short time coherent, broad-band and spatially coherent additional light source (8') which can be operated for light amplification or as a backup light source.

6. The measuring device according to one of the foregoing claims, characterized in that an additional device (9') for frequency shifting is arranged in the beam path of one of the two partial beams (16, 17) for frequency shifting the first partial beam (16) with respect to the second partial beam (17), and the device (9) and the additional device (9') for frequency shifting are acoustical-optical modulators.

7. The measuring device according to one of the foregoing

claims,
characterized in that
the beam splitting and receiving unit (13) is a spectral device for splitting the light into a plurality of wavelengths and a downstream photodetector matrix for selectively receiving these wavelengths;
the beam splitting and receiving unit (13) is also mounted in the unit (2);
the beam splitting and receiving unit (13) is coupled to the measuring probe (3) via the optical fiber arrangement (6), and the phase differences of signals from the individual detectors of the photodetector matrix are used for determining the shape or the distance of the measured surface.

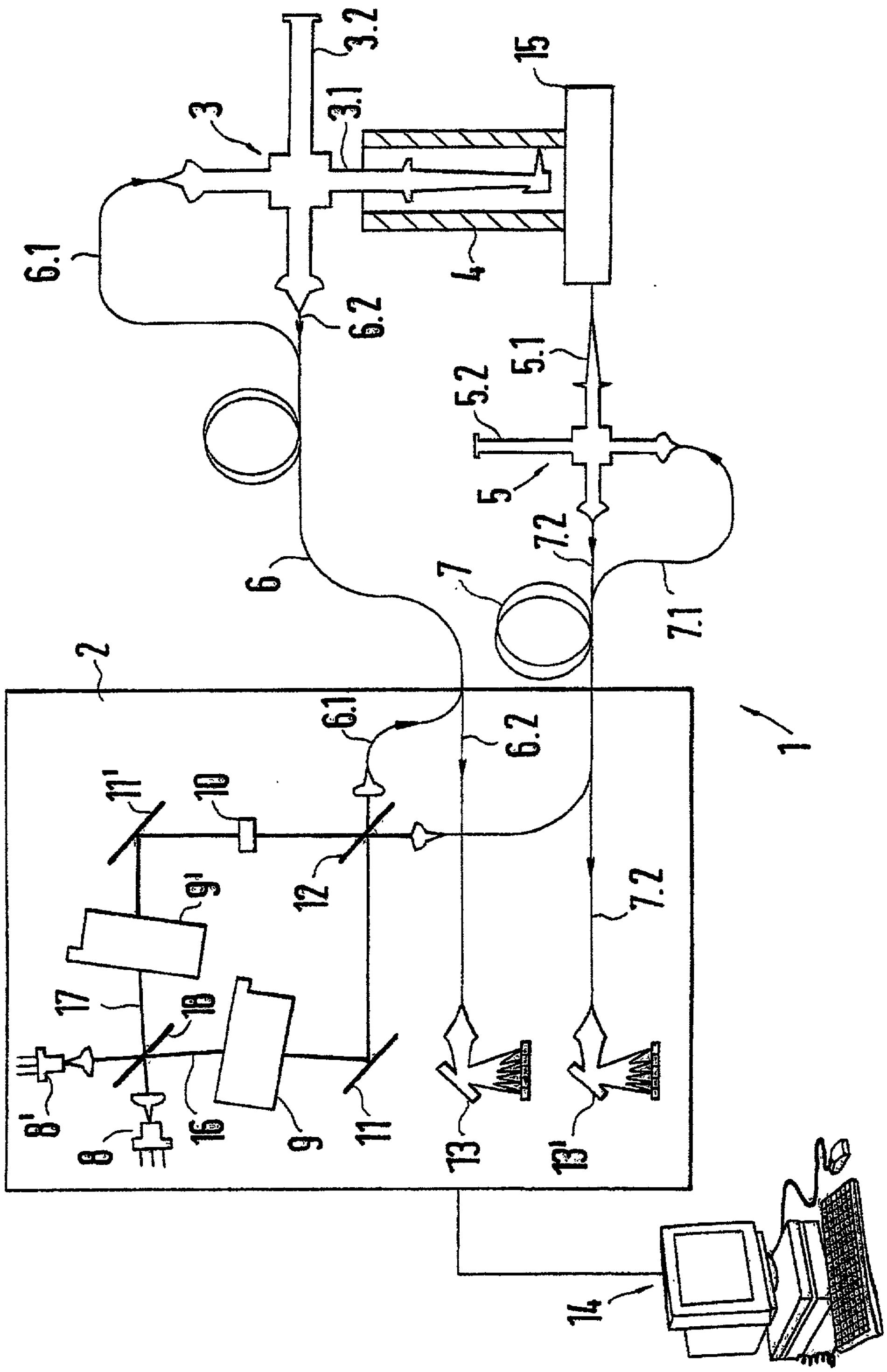
8. The measuring device according to one of the foregoing claims,
characterized in that
the measuring probe (3) having the measuring arm (3.1), the measuring reference arm (3.2), and a beam splitter of the measuring probe (3) is designed as a Michelson or Mirau interferometer,
and an optical path difference produced in the measuring arm (3.1) and in the measuring reference arm (3.2) compensates for the optical path difference produced by the time delay element (10).

9. The measuring device according to one of the foregoing claims,
characterized in that
an additional beam path is formed starting from the second beam splitter (12), leading to a reference probe (5) having a reference probe reference arm (5.2) and a reference probe measuring arm (5.1);
an additional beam splitting and receiving unit (13') is provided in the unit (2), and
the unit (2) is coupled to the reference probe (5) via an additional optical fiber arrangement (7).

10. The use of the measuring device according to one of the foregoing claims,
characterized in that
the measuring device is used for measuring the internal geometry of boreholes.

Abstract

An interferometric measuring device (1) for detecting the shape of rough surfaces is described, a spatially coherent beam gun unit being provided, which emits a short time coherent and broad-band beam, the device being separated into a section containing the components of a modulation interferometer (2) and the components of a measuring probe (3), and the measuring probe (3) being coupled to the modulation interferometer (2) via an optical fiber arrangement (6), being used remotely from the modulation interferometer (2) (Figure).



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COMBINED DECLARATION AND
POWER OF ATTORNEY FOR PATENT APPLICATION

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below adjacent to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled **INTERFEROMETRIC MEASURING DEVICE FOR DETECTING THE SHAPE OR DISTANCE IN PARTICULAR OF ROUGH SURFACES**, and the specification of which:

[ ] is attached hereto;

[ ] was filed as United States Application Serial No. ____________ on _________, 19__ and was amended by the Preliminary Amendment filed on ___________, 19__.

[X] was filed as PCT International Application Number PCT/DE99/00433, on the 16th day of February, 1999.

[X] an English translation of which is filed herewith.

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, §1.56(a). I hereby claim foreign priority benefits under Title 35, United States Code § 119 of any foreign application(s) for patent or inventor's certificate or of any PCT international applications(s) designating at least one country other than the United States of America listed below and have also identified below any foreign application(s) for patent or inventor's certificate or any PCT international application(s) designating at least one country other than the United States of America filed by me on the same subject matter having a filing date before that of the application(s) of which priority is claimed:

EL594606237US

PRIOR FOREIGN/PCT APPLICATION(S)
<u>AND ANY PRIORITY CLAIMS UNDER 35 U.S.C. § 119</u>

Country : Federal Republic of Germany

Application No. : 198 08 273.8

Date of Filing: February 27, 1998

Priority Claimed
Under 35 U.S.C. § 119 : [X] Yes [ ] No

I hereby claim the benefit under Title 35, United States Code § 120 of any United States Application or PCT International Application designating the United States of America that is/are listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in that/those prior application(s) in the manner provided by the first paragraph of Title 35, United States Code § 112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations § 1.56(a) which occurred between the filing date of the prior application(s) and the national or PCT international filing date of this application:

PRIOR U.S. APPLICATIONS OR
PCT INTERNATIONAL APPLICATIONS
DESIGNATING THE U.S. FOR BENEFIT UNDER 35 U.S.C. § 120

<u>U.S. APPLICATIONS</u>

Number :

Filing Date :

PCT APPLICATIONS
<u>DESIGNATING THE U.S.</u>

PCT Number :

PCT Filing Date :

I hereby appoint the following attorney(s) and/or agents to prosecute the above-identified application and transact all business in the Patent and Trademark Office connected

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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment or both under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

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Inventor's signature ______________ Date 30.08.2000

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